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Introduction

Undoubtedly, the most visible aspect of Ontario's electric power system is the network of transmission lines which criss-cross many square miles of the province. This is not surprising in view of the fact that the Ontario Hydro bulk power transmission system (i.e., the 500,000 volts (500 kV), 230 kV and 115 kV transmission lines) traverses a total distance of 11,200 miles and together with the associated rights-of-way occupies about 180,000 acres of land (this is a rough figure - it depends on the definition of "rights-of-way"). In a very real sense these lines (technically they are referred to as conductors) are the electric power arteries which provide Ontario's industry, commerce and homes with electric power and all that implies. The voltage levels of these transmission lines vary very widely ranging from 500 kV down to about 1,000 volts.

The cardio-vascular system of the human body can be thought of as being analogous to the electric power system insofar as, in the former case, the major artery (the aorta) connected directly to the heart(the power source), transmits much more "power" than the peripheral arteries, say, in the fingers; similarly, the electric power lines leaving the generating station transformers are at very high voltages, to improve the efficiency of transmission, while the peripheral voltage we use in our homes is normally at comparatively low voltage i.e., either 220 or 110 volts. Noteworthy is the fact that a 500 kV circuit can carry

from four to seven times the amount of power that can be carried on the next lower voltage level circuit i.e., a 230 kV circuit.

From strictly scientific, engineering and economic points of view, the more electric power generated in a system, such as Ontario Hydro, the stronger the case for introducing extra-high voltage (EHV) i.e., 500 kV - 765 kV or even ultra-high-voltage (UVH) transmission i.e., 1,000 kV and up. This is due to the fact that the higher the voltage used the less the thermal energy losses, and also the more economic the use of materials for tower structures, conductors, insulators, etc. On the other hand, however, the environmental problems associated with transmission lines may be exacerbated. What about, for instance, the impact of higher transmission towers on the natural beauty of the countryside or on the agricultùral potential of the land being traversed? There is also the question of reliability - if a major artery were to be disabled through severe weather conditions or structural failure, the system as a whole would be subjected to a "severe shock". But this appears to be a very infrequent occurrence.

In introducing this the fourth issue paper in the Commission's series it is important to recognize that Ontario's electric power system is an integrated system in which the processes of generation, transmission, transformation, switching, monitoring and control must be treated as a whole. In Issue Paper #7 consideration will be given to the implications of the so-called "total system". Suffice it to mention that an integrated system is necessarily an interactive system. Accordingly, the

criteria upon which the selection of a site for a major generating station are based must include criteria relating to the routing of the associated transmission lines and their potential for handling the power from other stations.

This paper will be mainly concerned with Ontario Hydro's bulk power transmission system and to a somewhat lesser extent with the transformer and switching stations associated with it. An excellent, very readable, introduction to the subject is provided in Dr. O. M. Solandt's Ivey Paper - "Bulk Transmission of Electric Power" which introduces the technical, economic, environmental, health and social aspects of transmission lines. The Solandt Paper isavailable in the Commission's Information Centre. The following quotation from it gives some of the basic operational data relating to Ontario Hydro's power transmission system:

> "Ontario Hydro's existing bulk power transmission system is mainly at 230 kilovolts (kV). Recently constructed lines are mainly at 500 kV and future construction will be predominately at this voltage. Virtually all of these lines are overhead. From the receiving terminal station to the area-supply transformer station the lines that operate at 230 kV or 115 kV are mainly overhead but are often put underground in urban areas. From the area transformer stations, power goes out at what are usually called sub-transmission voltages of 44 kV, 28.4 kV or 14.2 kV, so the distribution network fans out at constantly lower voltages until, finally, it reaches the consumer's electric stove or dryer at 220 volts and his lights and other small appliances at 110 volts."

As an electric power system grows, often with a concomitant increase in the size of new generating stations, there is an increasing trend towards standardization of 500 kV lines for bulk transmission. For example, at present there are about 15,000

circuit miles of 500 kV lines in North America. In Quebec some bulk transmission is carried out at 735 kV and in Europe even higher voltages are being planned. Indeed, during a recent visit of the Chairman and Bob Rosehart (Scientific Counsellor to the Commission) to Europe it was stated that, within 20 years, 1,000 kV or 1,500 kV transmission networks will be required in the United Kingdom and several European countries.

It is convenient to consider the "transmission system" issues under the following headings: Technical and Planning Factors; Siting and Routing; Health and Safety; Environmental Impact; Socio-Economic Factors; and Alternative Technologies. As in previous issue papers, several Appendices have been included to provide references, to the transmission and distribution of electric power in Ontario, in the transcripts of the Commission's meetings and hearings, and also in the memoranda, submissions and research reports which relate to the inquiry.

I. Technical and Planning Factors

It is very probable that some of the fundamental issues which will be considered during the final phase of the Commission's inquiry will be closely related to the technology of the bulk power transmission system and related topics. Consequently, some knowledge of the technical aspects of electric power transmission is desirable not least because it will be helpful in developing a better understanding of the associated socio-economic, health and environmental aspects. The purpose of this section is to outline the basic operating characteristics of Ontario Hydro's bulk power transmission and distribution system. They are summarized below.

i) The majority of the world's large electric power systems, including Ontario Hydro, are essentially 3-phase a.c. systems. This is because, at present and in the foreseeable future, the generation, transformation, and transmission of electric power in this form is more economical, more convenient and more reliable than any other well-established method. However, in certain circumstances, especially when very long bulk power transmission lines (say in the order of 1,000 miles) are involved, or when two asynchronous (in the sense of being "incompatable") electric power systems must be linked, then d.c. transmission is becoming an increasingly attractive alternative. It is also well known that the distribution of electric power to residential areas is normally in the form of low voltage single-phase a.c. power.

ii) The circuit mileages projected to 1980, for the three basic voltages in the bulk power transmission system of Ontario Hydro are shown in Table I.

TABLE I

ONTARIO HYDRO

CIRCUIT MILEAGES TO 1980

Voltage	Circuit Miles
500 kV	1571
230 kV	8249
115 kV	6739

iii) How is the transformation of a.c. power carried out? For the very high voltages massive power transformers are used, for example, to convert from 500 kV to 115 kV, on the other hand, at distribution voltage levels, the comparatively small transformers mounted at the top of Hydro poles are used. All transformers are comparatively low energy loss devices and therefore very efficient. However, the transmission lines themselves are subject to comparatively high losses of energy, in the form of thermal energy. For instance, in the case of a 500 mile EHV transmission line the losses are in the order of 10% of the energy transmitted. Note also that in the cases of both transformers and transmission lines the limits to the electric loads which can be handled are determined by the maximum temperatures that can be tolerated and the thermal energy that can be dissipated. One of the virtues of overhead power lines (as will be pointed out later they also have some disadvantages) is that air is a good insulator, and the lines can be strung at appropriate distances apart. Furthermore, the thermal energy generated in the lines can readily be dissipated as compared, for example, with the insulation and heat dissipation problems associated with underground cables.

iv) What are the main considerations which determine the "loading" of a transmission line? The major ones (some of which are interdependent) are the voltage level, the energy losses, the thermal limits which are associated with the mechanical strength of the line, the insulation characteristics, and the characteristics of the protective relay system associated with the line. Of course, the overriding considerations are the safety reliability and stability of the electric power system as a whole. It is interesting to note that apparently the 500 kV, 2-circuit transmission line is optimum from the points of view of power transmitting capability under various line loss circumstances, maximization of the use of land, and from the point of view of lower cost, as compared, for example, with 2-circuit and 4-circuit 230 kV lines and 1-circuit 765 kV lines.

v) What about the alternative technologies in electric power transmission and distribution? - these will be considered briefly in section VI of this issue paper.

As pointed out previously it is the bulk power transmission system which makes possible an "integrated system". And as a consequence the reliability of the system as a whole is enhanced. It is understood, for example, that the reliability of the bulk power transmission system, per se, is exceptionally high - the majority of forced outages, in general, are usually caused by circuit faults in the low-voltage distribution networks (e.g., damage caused by icing, wind, hydro-poles being hit by trucks or cars, etc.). Unfortunately, unlike the generation component of the total power system, in which the overall system reliability can largely be determined by the level of "excess margin", the transmission system is much more difficult to assess in terms of "excess capacity". One of the major unsolved problems is an adequate mathematical model of the system as a whole. However, considerable advances have been made recently in the development of network analyses and simulators. The question of "reliability levels" for the bulk electric power network is related, of course, to questions concerning the need for additional EHV transmission lines. Paragraph 4 of the Commission's terms of reference exemplifies the question - how can the "need" for a specific transmission line be adequately assessed?

Some of the issues relating to the more technical aspects of transmission lines are:

- to what extent can bulk power transmission lines be upgraded by technical means without unduly limiting their expected life, or the stability of the system? Is

this option always taken into account before additional transmission capacity is constructed?

- are there any technical difficulties which might prevent an increasing number of companies, and individuals, with self-generation capabilities, from being integrated into the Hydro system, i.e., receiving power and providing power? - can the increasing length of the lead times involved in the construction of the bulk power transmission lines be reduced by technological advances? For example, what is the potential of large heavy-duty helicopters?

- what is the future potential of d.c. bulk power transmission in Ontario Hydro's system? There are undoubted advantages in d.c. bulk power transmission (notably in efficiency of transmission and system stabilization, economy of land utilization, economy of conducting materials, smaller towers and hence less aesthetic impact, and no alternating electromagnetic fields) and also some disadvantages notably the high cost of the terminal equipment (for converting a.c. to d.c. and vice versa).

- in the field of materials research are there any significant developments in hand which might markedly affect the design of future transmission lines, including insulators?

II. Siting and Routing

The route selection and site location processes constitute some of the most difficult tasks involved in the planning of an electric power system. This is because not only do these processes have rather sophisticated technological dimensions but there are also many socio-economic and environmental dimensions involved. Some of the latter are subject to major government legislation such as The Planning Act, The Expropriation Act and the Environmental Assessment Act. These regulatory procedures provide, on the one hand, means for protecting man and his environment, but on the other hand, they usually give rise to increasing lead times (as described in Issue Paper #2) and these

in turn may delay the provision of urgently needed facilities.

The main steps in route and site selection processes are summarized below:

i) The determination of where and when additional facilities are required.

ii) The development of alternative methods for meeting the requirements.

iii) The evaluation of the alternative proposals.

iv) Recommendation of one of the alternatives.

In the assessment of the alternatives, a wide range of criteria are used together with appropriate weighting factors. These are described in some detail in the "Transmission-environmental" Memorandum submitted by Ontario Hydro to the Commission, but this material is beyond the scope of this issue-paper. It is perhaps interesting, however, to note two of the many factors which have to be taken into account i.e., the "right-of-way requirements" and the cost per mile of certain transmission line configurations. These data are given in Tables II and III - the information is taken from O.M. Solandt's Ivey Paper, "Bulk Transmission of Electric Power". The advantages of using 500 kV or 765 kV as compared with lower voltages is very marked from the standpoints of minimization of right-of-way width and the cost per mile.

Table II

Right-of-Way Requirements

(Transmit 4,000 MW for 100 Miles)

Voltage (kV)	Capacity Per Circuit (MW)	Number of Circuits	Right-of-Way Width (Ft.)	Right-of-Way Per Mile (Acres)
115	30	133	5025	610
230	140	29	1200	145
500	2200	2	200	25
765	4300	1	135	15

Table III

Number of Lines	Per Mile Cost *	R/W Width (ft)
one 2-cct 500 kV	$ 600,000	250
four 2-cct 230 kV	1,200,000	530
seven 2-cct 230 kV	2,100,000	950

* Per Mile Costs do not include property, legal costs, etc.

One of the key steps in the routing of transmission lines is to identify alternative "bands" which would adequately satisfy acceptable environmental, economic and technical criteria. It has been pointed out that the final choice of the "band" must not only be predicated on the immediate requirement but also on potential generating facilities and associated transmission line requirements. This is understandable and good planning practice. However, might not the very existence of a particular EHV line have an important influence on future generating station site selection? The routing of transmission lines from the Bruce Generating station to the London region, and between the Lennox Station and Toronto exemplify this possibility. There is concern among the farming communities that certain routes may encourage the development of new generating sites in areas categorized as class 1 and class 2 farmland. The same concern applies also, of course, to the siting of major transformer and switching stations.

Some of the major issues and concerns relating to the siting and routing of transmission lines are summarized below:

- how effective is the public participation process in the siting of generating stations, the routing of transmission lines and the siting of major transformer and switching stations? To what extent is the public involved in establishing weighting factors in connection with the route selection process?

- concern has been expressed relating to the long-term implications of a selected transmission line corridor e.g., once this has been established it has been suggested that the choice of future generating sites in the same geographical region will obviously be influenced by the availability of the corridor. How can the confidence of the farming community be restored?

- how desirable are multi-purpose corridors? - e.g., transmission lines; gas pipe-lines; highways? It has

been suggested that it might be feasible to close certain concession lines and to use these as electric power corridors and thereby to minimize the impact on farmlands - is this a viable possibility? Similarly, have unused railway rights-of-way been considered?

III. Health and Safety

Especially in the farming communities there is much concern about the health and safety aspects of EHV transmission lines. Is it safe to operate farm machinery beneath transmission lines? What are the health consequences of comparative lengthy exposures of humans and animals to the electromagnetic (i.e., similar to radio waves but at very low frequencies) and the electrostatic (i.e., akin to the electricity generated by friction and the "shocks" we sustain when the humidity is very low in our homes) fields due to transmission lines? Are these biological effects, if any, cumulative? These and many other questions in a similar vein were raised chiefly during the Commission's meetings and hearings which were held in several agricultural counties of the province. They are particularly relevant to the inquiry.

Insofar as the health effects due to lengthy exposure to the electric fields due to transmission lines on humans and animals are concerned there is an increasing recognition of the importance of basic research in the subject. At present several basic investigations are being undertaken. In some countries, including Canada, Britain, the United States, and the U.S.S.R. continuing studies of the long-term health effects of high voltage fields on electric utility line workers are in hand.. One of these is a major study, being undertaken by Ontario Hydro in collaboration with the University of Toronto which was launched last year. This research involves regular physical examinations of a random sample of Hydro linemen, and monitoring of the physical conditions of the lines - an extensive computer analysis of the data is being

undertaken. Further, laboratory-oriented investigations of the effects of electric fields at power-line frequencies on chicken embryos, voles, trees, plants with pointed leaves, swine and honey bees are being conducted in several major laboratories. Notable too is the work of Drs. Becker and Marino at the University of Syracuse on the effects of induced electric currents on bone as well as the effects on the central nervous system - the experiments have been, and are being, undertaken with laboratory animals. To date there appears to be conflicting evidence relating to the health effects of exposure to alternating electric fields - the Commission is attempting to collect together as much of the relevant scientific literature as possible for the benefit of the many farmers who have expressed interest in the subject.

Closely related to the health implications of the alternating fields due to transmission lines is the safety aspect. It is well known, for example, that some farmers, working in the vicinity of transmission lines have experienced electric shocks - not necessarily dangerous but certainly unpleasant. What are the effects of alternating electric fields on people with certain disabilities? - one example that comes readily to mind is the farmer with a "pacemaker" or other implanted electronic device. This is an important question. Some of the effects can probably be minimized by adequate insulation and grounding, whichever is appropriate, of farm implements, wire fences, pipes and other equipment in the vicinity of transmission lines. Buildings are not allowed under transmission lines. The safety of transmission lines and towers during severe electric storms and under high wind

conditions are topics of some concern although human fatalities and injuries from these causes appear to be very rare - to date we have not obtained any information on the effects of such hazards on animals.

Of quite a different kind is the potential impact on human and animal health, as well as on crops, of certain toxic substances which are associated with electric power transmission and distribution. Perhaps the best known is ozone, a toxic gas which is produced by the electrical discharges (generally referred to as "corona"discharges) which frequently occur across insulators during very damp weather conditions. As pointed out in Issue Paper #3, ozone is also an undesirable by-product of the combustion of the fossil fuels, and its effects, even at distances 200-300 miles from the source, on certain crops may be very harmful. Present indications appear to be that the major source of the ozone is not the "corona discharges" but more probably the combustion of fossil fuels. However, investigations are continuing.

Another potential hazard has arisen with the increasing use in transformer and switching stations of sulphur hexafluoride (SF_6), a gas which although harmless in itself can cause conditions conducive to asphyxiation because air is excluded from the atmosphere. The great merit of this chemical is due to its excellent insulating characteristics this means that, using SF_6 as insulating medium, high-voltage components can be placed much closer together than when air itself is the insulator. As a consequence it is now possible to design switching stations,

based on SF_6 insulation, in an area about a tenth the size of formerly and this, clearly, has important land-use and environmental implications.

The third chemical which is potentially hazardous if it escapes from its container is the liquid "Askarel", (this is its trade name) which is an excellent electric insulator which is virtually indispensible in the design of very large transformers and other high-voltage electrical components. Unfortunately this substance is one of the class of non-biodegradable polychlorinated biphenyl (PCB) compounds. These are well known pollutants which, because of their persistence and toxicity can enter food chains at various levels with profoundly undesirable ecological consequences.

Many issues have been raised in connection with the health and safety aspects of transmission and distribution technology - some of these are of a highly scientific and technological kind and do not lend themselves readily to public discussion (e.g., the detailed researches in hand to find a less toxic, non-PCB based compound as a substitute for "askarel" is such an example), however, other issues such as the following may be of more basic concern and interest:

- assuming that the current researches into the biological effects of high-voltage transmission lines demonstrate that there are indeed harmful effects arising from continued exposure to these electric fields; what steps might be taken to safeguard employees of Ontario Hydro exposed to such fields and also farmers who may be so exposed?
- are the protection measures to guard against the potential hazards associated with high-voltage transmission lines and transformer and switching stations adequate? Is the farming

community, in general, aware of the nature of the hazards associated with transmission lines? What about the special case of handicapped people (e.g., with implanted "pacemakers") who may be more susceptible to the electric fields in the vicinity of transmission lines? Are they made aware of the potential hazards?

- to what extent do the new generation of large agricultural machines, of considerable height, and the use of "gun-type irrigation equipment" constitute hazards in the vicinity of transmission lines? What about potential hazards to aircraft involved in spraying crops?

- to what extent is Ontario Hydro participating in researches concerned with the impact of ozone on people, animals and crops?

- do any of the health hazards, mentioned above, have really serious implications, and if so, how should they be weighed in the planning of electric power systems? Are there any unanswered questions in this general area which are causing concern among the "experts"?

IV. Environmental Impact

Not only man and animals but all facets of the natural environment are probably affected in some degree when a transmission line is constructed across the countryside. Indeed it is well known that, during construction, damage to soil and vegetation near tower sites is virtually inevitable. And certain steps are being taken to minimize this impact by "stringing" the conductors in such a way that heavy equipment is needed only every five miles or so thereby reducing damage to the soil by compacting. The use of helicopters in construction work would also minimize soil compacting but the cost would undoubtedly be high.

The environmental impact which may result from the clearing of vegetation in rights-of-way and the exposing of streams have been well documented. In particular the ecological balance may be upset because of the disturbances to wildlife and to fish. It is understood that steps are being taken to remedy this potential imbalance by replanting appropriate vegetation and by practicing "selective cutting" at all times. Indeed, it has been pointed out that in heavily forested areas, selective cutting of a right-of-way may substantially benefit wildlife and provide a more favourable environment for small animals and birds.

From an aesthetic standpoint the impact of transmission lines on the natural beauty of the countryside is cause for considerable concern among nature lovers and especially "environmentalists". Indeed, it is this high visibility which

probably focuses attention on transmission lines as a "major culprit" in a whole range of environmental insults - this may not be justifiable. In spite of major efforts in many countries to minimize the visual impact of transmission lines there does not appear to be any immediate prospect of breakthroughs in this respect. For example, the modern single-shaft pole structure, which is more costly than the conventional lattice structure, is being used increasingly by some European countries and is being used on a comparatively small scale in Ontario. The width of the right-of-way itself contributes to the visual impact - the wider the corridor the more the impact and, of course, the greater the area of land involved.

The environmental impact of transformer and switching stations of the conventional and the modern (i.e., SF_6 insulation) are essentially the same, on a different scale, as those associated with transmission line corridors. With the possible exception that the concentration of ozone in certain weather conditions may be slightly greater in the case of large switching stations than in the vicinity of transmission lines. But this is not a significant factor.

The issues which relate to the environmental impact of transmission line corridors are summarized below:

- the Ontario Environmental Assessment Act, which is administered by the Environmental Assessment Board, will probably act as a "guardian" and as a regulator of environmental impact insofar as transmission line corridors, and indeed all major electric power facilities, are concerned. The public hearings of the Environmental Assessment Board will provide ample opportunities for environmentally-oriented public interest groups, for farmers

and for the public in general to express their points of view and thereby to broaden the basis for the decision making process. How well known to the general public are the provisions of this extremely comprehensive legislation?

- are the standards for the control, and repair of land, and for any environmental damage due to construction and maintenance activities considered to be adequate?

- are the measures being taken to ensure minimum impact on the ecology and minimum visual impact of a transmission corridor generally acceptable?

- in order to minimize the width of the right-of-way, and at the probable expense of higher towers, would the public accept multi-line transmission towers (in West Germany as many as sixteen lines are strung on single towers)? Are these technically and economically viable in Ontario?

- is the public willing to pay the extra cost of the more aesthically appealing pole-type transmission towers? (Note that the cost may be double that of the conventional lattice-type towers and the disturbance of agricultural land because of the depth of the footings may be appreciably greater.)

V. Social and Economic Factors

The social and economic impacts of electric power transmission and distribution are many and varied. Some of these fit more appropriately into issue papers presently in the planning stage. For example, Issue Paper #5, following this present paper will be devoted to Land Use, and topics such as Land-Use Legislation and Guidelines for Policy, and Land-Use aspects of Ontario Hydro facilities will be considered, while Issue Paper #8 will be devoted to Public Participation and the Decision-Making Process. Clearly each of these subjects might be categorized as social and economic factors concerning electric power transmission. Yet another example of the multiplicity of associations and interactions between the issues which will be raised in the series of issue papers as a whole.

Perhaps the social and economic aspects of the impact of transmission lines, which traverse farmlands, is the most contentious issue in this category. The major concerns relate to the compaction of soil, damage to drainage tiles, damage to fence lines (in consequence of the need for access to the corridor and the use of comparatively heavy implements in the construction process), and not least the overall disturbance created on the farming operation as a whole. And there are other specific problem areas. For example, another most important concern is the potential loss of value of land which is traversed by transmission lines, and if the land is reasonably close to growing towns and cities the problem is exacerbated.

In an urban environment the location of a transmission line corridor close to homes may be regarded as a desirable feature by the homeowner because the corridor provides a measure of privacy and perhaps even a recreational area which would otherwise be taken up with another sub-division. It is interesting to contrast the differing viewpoints between the urban and the rural homeowner (or farmer).

Of increasing importance is the concept of public participation in decision-making processes involving major public works such as electric power lines, generating stations, pipe-lines, etc. In Ontario the participation of the public in hearings and meetings relating to the routing of transmission lines has been particularly noteworthy. The public hearings of the Solandt Commission and the Environmental Assessment Board have provided opportunities for such participation and, on a more informal basis, meetings conducted by Ontario Hydro have provided other opportunities. Public participation, as was mentioned previously, is considered by the Commission to be central in its inquiry and for this reason Issue Paper #8 will be devoted exclusively to this topic.

The economic implications of transmission lines, from the standpoint of the devaluation of the property which they traverse can be a significant factor. In Issue Paper #5 the special case of the farmer owning land forming part of a transmission corridor will be introduced as well as the general economic considerations relating to the land used for the transmission of electric power. It will suffice in this paper to mention the question briefly.

The basic point which has been raised is that not only does a right-of-way remove perhaps Class 1 and Class 2 land from cultivation, but it may also, especially in suburban regions, reduce the value of the land as part of a potential housing sub-division. While, as Professor Norman Pearson has pointed out, transmission lines may actually have the effect of protecting good farmland from urban encroachment; however, this is small consolation to a farmer who may be relying on the sale of the land for his future retirement pension.

There is also the ubiquitous problem of continuing expansion. After the establishment, for example, of certain major electric power facilities, in a specific rural area, there is always the possibility that these may be expanded in the future, perhaps to handle extra generating capacity, and there will be a concomitant need for new transmission lines in the area. This appears to be a continuing concern for many farmers and country home-owners.

Issues of a social and economic nature relating to transmission line construction and maintenance may be summarized as:

- to what extent is the problem of the devaluation of land traversed by transmission lines resolvable? Is adequate compensation provided for those people, especially farmers, who are affected?

- are the criteria upon which compensation for damage to the land, loss of land and inconvenience regarded as being fair to all concerned?

- in view of rapidly changing social and economic circumstances, is the legislation, such as the Planning Act, the Expropriation Act and the Environmental Assessment Act

still adequate or is there need for updating of the legislation?

- what is the impact, if any, of transmission lines on the life-styles of people living and working in their close vicinity? For instance, is there a continuing awareness of their very existence, apart from the economic implications referred to above, do people become conditioned, as in urbanized areas, to transmission lines, transformer and switching stations, and indeed even generating stations?

VI. Alternative Technologies

When we refer to the potential of "alternative technologies" we have in mind the possible introduction of different ways of doing things - not necessarily new ways - which may be more socially, environmentally (from both health and ecological perspectives) and economically desirable, but also existing technologies which may have been known for many years (e.g., the d.c. transmission of electric power pre-dated a.c. transmission and was being utilized at the end of the last century). Moreover, we are contemplating and anticipating the future because alternative technologies may take at least a decade, or even two, to introduce on a practical scale. But because the Commission is future-oriented, and because of the rapidity of technological change it behooves us to draw the attention of the public to alternative technologies which may have an important role to play in the future planning of electric power systems. In previous issue papers, especially those concerned with electric power generation, alternative technologies have been important issues.

Insofar as the transmission (and distribution) of electric power is concerned various alternative techniques and technologies should be mentioned - four of them are introduced briefly below:

i) Although Ontario Hydro does not contemplate the use of ultra-high voltage transmission - 765kV and higher - for at least the next 15-20 years, the technologies are already available, and indeed are in use by some utilities, including Hydro Quebec, and no doubt many people will wish to know about the pros and cons of UHV transmission. The main advantage appears to be the increased efficiency of transmission especially over long distances (say, in the order of 1,000 miles). On the other hand, however, the cost of transmitting power

may be increased slightly and health, environmental and social implications may be somewhat exacerbated. During the forthcoming era when the efficient utilization and the conservation of energy are likely to be major concerns, there may be a case to be made for UHV transmission, on a limited scale, in Ontario before the end of the century.

ii) The potential, and the problems, related to the use of underground cables have been introduced previously. At present the major disadvantage is economic and until the cost of SF_6 insulated underground cables and also of cryogenic cables (these cables are based on the principle that the electrical resistance of some metals and alloys is virtually negligible at very low temperatures, i.e., temperatures of -260°C - the technology of producing and maintaining these cables is well established) is appreciably reduced, perhaps by a factor of at least 10, they are in no way competitive with conventional transmission lines. On the other hand, there are obviously health, social and environmental advantages accruing from the use of underground cables. It seems likely that in urban areas and suburban areas the trend will be towards replacing overhead transmission lines with some form of underground cables (interestingly the major problem with underground cables is to dissipate the "lost energy" which is generated in the form of heat). By the end of the century, through major advances in the technology, not least the cutting down of cost, there appears to be a reasonable probability that underground cables will be used exclusively in urban and suburban areas and that there will begin to be some penetration into the rural countryside.

iii) Mentioned previously was the increasing use of SF_6 insulation for switches and relays in transformer and switching stations. The incredible advantage is in land utilization as compared with conventional air-insulated systems. This is not really an "alternative technology" but attention is drawn to it again because of its potential in the future.

iv) d.c. transmission has been well known for almost a century, and it is being used by some utilities on a limited scale. Its advantages are that fewer conductors are required, as compared with 3-phase a.c. transmission, that lower towers and narrower rights-of-way will suffice and that d.c. electric fields may have less biological impact (if this is established) than a.c. electric fields. In addition, there is the potential advantage that d.c. links facilitate greatly the linking together of two electric power systems which are nominally "asynchronous" (i.e., the a.c. voltages are not "in phase"). As a matter of interest Hydro

Quebec is linked to New Brunswick by a d.c. link and Manitoba is linked to Northwestern Ontario in the same way.

At present the major disadvantage of d.c. transmission arises for two reasons, first, the high cost of the terminal equipment which converts a.c. into d.c. and vice-versa, and secondly because the reliability at present does not appear to be quite as high as that achieved using conventional a.c. transmission. Nevertheless, the technology is being developed in many countries, notably in Sweden, and West Germany, there is also some first-class research and development in d.c. transmission being undertaken in the research laboratories of Hydro Quebec. The potential of d.c. transmission in Ontario, on a limited scale within the next ten years appears very promising.

v) It has been suggested that one way of eliminating electric power transmission and distribution systems is to convert, at source, electric power into a liquid fuel. It is well known that electricity will "electrolyse" ordinary water into its constituent parts of hydrogen and oxygen. If this process can be conducted on a sufficiently large scale if hydrogen were (perhaps converted to methane by a chemical process - methane is essentially natural gas) then energy could be transferred from an electric power station to the consumer via pipe-lines. This whole approach has been referred to as the basis of a "hydrogen economy". Its merits include minimization of environmental and health impacts and especially, assuming that liquid fuels can be produced from the hydrogen, a new fuel for transportation and many other purposes would be available, thereby reducing the requirements for crude oil and natural gas. The potential of this approach remains to be worked out in detail - if we were asked to speculate we would probably conclude that the "hydrogen economy" is unlikely before the end of this century.

v) There have been several "way-out" ideas , proposed during the Commission's meetings and hearings, for the transmission of electric power in the future. One of these - "wireless transmission" - has been advocated quite strongly by two or three devotees. However, to date, the Commission has not obtained any scientifically based evidence which supports the idea.

An "omnibus" issue which relates to all the above possibilities is:

- is Ontario Hydro conducting adequate research and development programs in the above technologies, or perhaps

more realistically, in those technologies which appear to have potential for the electric power system before the year 2000? If so, to what extent is the current state of these researches available to the general public?

APPENDICES

The attached appendices provide first, comments relating to the transmission and distribution of electric power which were made at the Commission's Preliminary Public Meetings and the Public Information Hearings; secondly, specific references to the subject in the transcripts of the hearings; and thirdly, references to the subject included in the Research and Background Papers prepared for the Commission. More detailed information on "Transmission and Distribution" is contained in the transcripts, memoranda, submissions, and research documents which are available in the Commission's Information Centre, 14 Carlton Street, Toronto, Ontario M5B 1K5 and in the Regional Depositories located in the Main Libraries in Thunder Bay, Sudbury, London and Ottawa.

Appendix A

Some References to

Transmission and Distribution Issues

Made During

The Preliminary Public Meetings

I. Technical and Planning Factors

"By increasing the voltage you can transmit maybe twice or three times as much power by going to the higher voltages and this means less corridors. It may be that we could increase the transmission density of our power lines more economically than some other solutions." S 292

"Instead of running high voltage transmission lines as the crow flies to their destinations; there should be an investigation of the possibility of using existing corridors such as highways, railway lines, or even farmers line fences." S 110

"Large and extensive transmission systems may be efficient in switching energy from one area to another. It should also be remembered that a large system is far more vulnerable to damage by a terrorist activity than a number of smaller ones. The ecological analogy here is the fragility or vulnerability of an ecosystem with few species as compared to the stability of an ecosystem made up of a large number of species." S 226

"I believe the siting of generating stations and transmission corridors is best left to the engineers who are required to provide alternate routes and sites and the economies of each selection." S 24

"The engineering rationale must form the major part of any of the decisions regarding the route and the cost." p. 161 V 2

II. Siting and Routing

"Can linking corridors between generating stations be ignored when planning site location?

i) How many linking corridors could have a less damaging north-south orientation?
ii) To what extent would east-west linkages be unavoidable?" S 60

"The effects of wide transmission corridors across both valuable forest land and farmland should be examined prior to granting permission to locate a generating station a great distance from actual need. Again, early approval of the priority items would render these studies superfluous." S 342

"I take exception to the thought that Hydro corridors having no significant effect on regional or provincial agriculture." S 266

"We get the impression that transmission line routing is becoming a matter of local preference favouring the more eloquent and vocal group, without due consideration being given to cost or operational efficiency." S 28

"Many people - rightly or wrongly - feel that the Ontario Hydro has been less considerate than it should have been of the individual rights of the property owners." p.1232 V 9

III. Safety and Health

"The use of large machinery close to towers especially at night is very risky." p.2243 V 17

"As a mother of 3 small children I view with grave concern my being forced to live and work under those lines.

What are the possible effects of all this electricity on the pregnant mother and her unborn fetus living and working under or close to these lines for months on end." S 267

"Although the danger of a child retrieving a ball from a transformer enclosure has been highly publicized by Ontario Hydro, the dangers to a farmer-operator have been kept hidden." S 262

"We can definitely conclude that building transmission lines across agricultural land will make farming operations both inefficient and dangerous."	p.2215	V 17
"Recent studies have shown harmful effects upon labourers working with 400,000 volt and 500,000 volt lines."	p.1367	V 7

IV&V Environmental and Socio-Economic Factors

"We may not be experts in the economies of power corridors, but we do know our communities in ways in which the experts cannot."		S 253
"Our prime concern is whether future generating sites and transmission lines should be allowed to encroach upon the bread basket lands of this Province. Must the heritage of leading food-producing lands be destroyed by the careless placement of generating stations and transmission lines."		S 137
"The transmission corridors themselves will consume food land, but the generating stations and the associated developments that they attract will consume far more."	p.2216	V 17
"We can object to tower line routes across the farms: - but we must be prepared to accept the potential of restricting our economic and industrial progress"		S 42
"It seems incongruous to me that we still campaign for four lane controlled access highways across our farmland and then violently protest hydro tower lines across the same type of four lanes."		S 42
"We believe that some productive use can be made of land represented by transmission line corridors."		S 28

VI. Alternative Technologies

"As an individual I must say that I do not appreciate the large tower structures that are now in conventional use for Hydro distribution. Why can't these cables run underground?"		S 107

"Water power, converted to electricity has great advantages if electric power could be transmitted over long distances without wires ... but no company or nation has ever applied this technology on a large scale."		S 381
"Today, in the 1970's, we have still this primitive technology of delivering power; this is the kind of technology that was used to deliver power at the turn of the century."	p.1050	V 7A
"Up to 10% of the electrical energy produced is lost in transmission through wires."	p. 957	V 7

(Underlined codes refer either to the submission number or the volume number of transcripts made as part of the Preliminary Information Hearings.)

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Transcript References To
Transmission and Distribution Issues
In the Public Information Hearings

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I. **Technical and Planning Factors**		
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- cause for failure	48	6039-
- Cornwall & Quebec Hydro	48	6034-6038
- design principles	48	6017-
- highlights - McClymont	48	6011-
- highlights - Harris	48	6097-
- monitoring of microwave towers & stations	48	6067-6069
- "PCAP" program - description and limitations	48	6042-6063
- security against vandalism & terrorism	48	6064-6078
- security criteria	48	6081-
- security is more important than availability - McClymont	48	6013-6014
- sky wires	48	6023-6025
- transformers		
- repairs & replacements	48	6071-6077
- sizes & weights	48	6078-6080
- transformer & switching stations		
- circuit breakers		
- vacuum type	12	1492-
- equipment suppliers	12	1489-1491
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- power factor correction		
- equipment	12	1494-1495
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- protection systems	12	1495-
-DACS	12	1498-1508
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- load shedding	12	1508-1509
- future developments	12	1521-1524
- transformers		
- three phase vs single phase	12	1492-1494
Transmission lines		
- UFO's incidents - Woodman	15	1876-1877
- Transmission corridor and generation planning - Bisset	15	1866-1868
- AC transmission	11	1416-

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- Hydraulic Generation and Transmission Division - role of	54	6690-
- land use considerations	54	6743-6746
- O.H. system is integrated	54	6748-6762
- advantages	54	6750-
- interconnected grid has more stability	54	6755-6762
- Hydro-Quebec has stability problems	54	6759-
- Ontario Hydro transmission system	54	6712-6762
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- generation and load areas	54	6712-6713
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- planning process for transmission system	56	7003-7034
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- alternatives, development & evaluation	57	7075-7081
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- need, determination of	56	7003-7034
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- banking of land	57	7057-
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	57	7049-7051
- two-stage process	56	7015-7033
- planning objectives	57	7115-7118
- provincial planning and Hydro's input	57	7147-7156
- micro-wave system	57	7127-7144
- protective relaying	57	7127
- definition, objectives, etc.	54	6685-
- simulator demonstration	55	6811-6867
- causes of faults	55	6843-
	55	6857-
- frequency considerations	55	6863-6867
- stability - dynamic & transient	55	6828-
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- system analysis, methods of	56	6912-6946
- analogue method	56	6915-
- definition - system analysis	56	6913-
- IREQ model	56	6915-
- 'DACS', use in	56	6922-6924
- Eigen-value program	56	6932-
- load flow program	56	6925-
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- compensation for lost production	14	1686-1688
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- claims for damages	14	1694-1699
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- ecological effects and quality of life	14	1754-1755
- construction	12	1462-1467
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- micro-wave transmission	57	7119-7126
- no revolutionary changes forseen for the next 20 years or so -McClymont	57	7121-
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-ducted air medium underground transmission	11	1415-1416
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References To Transmission and Distribution in Ontario Hydro Memoranda at the Public Information Hearings

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References to Transmission & Distribution in Ministry Submissions at the Public Information Hearings

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Economic and Regional Development Considerations		
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References to Transmission & Distribution in Other Submissions at the Public Information Hearings

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Ontario Natural Gas Association	30	
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Land Use Implications		
- Transmission and Distribution of Power		
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- Transmission and Distribution of Power		
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Appendix B-5

Public Information Hearings

List of Exhibits

related to

Transmission

Topic #5: Transmission Technical

Exhibit #	5-2	Chart illustrating the galloping Problem of transmission lines in Icy Weather.

Topic #6: Transmission Environmental

Exhibit #	6-1	Chart entitled "Area of Environmental Inventory for Phase 1 Studies, North Channel Station".
	6-2	Timber use capability. Chart entitled "Incorporated of North Channel GS".
	6-3	Forest Species Association. Chart entitled "Incorporation of North Channel GS".
	6-4	Forest Vegetation Age Classes. Chart entitled "Incorporation of North Channel GS".
	6-5	Disturbance of Forest Cover. Chart entitled "Incorporation of North Channel GS".
	6-6	Situation indicated as D.A. on Forest Product Map.
	6-7	Timber Production. "Incorporation of North Channel GS number f-3".
	6-8	Chart entitled "Other Areas of Concern".
	6-9	Chart entitled "Timber Production Situations D.A.".
	6-10	Composite Ranking.
	6-11	Constraint map ranking situations No. C1.
	6-12	Incorporation of North Channel No. C2.
	6-13	Incorporation of North Channel No. B1.
	6-14	Statements of Qualifications.
	6-15	Form provided by Mr. Chai Kalevar Requiring Information.
	6-16	Table of Sulphur Hexafluoride concentrations.

Topic #7: Socio-Economic Factors

Exhibit # 7-2 Booklet "Acquiring Land for High Voltage Transmission Lines".

Topic #20: Reliability

Exhibit # 20-4 Documents regarding the Bulk Power Transmission System.

Topic #22: Transmission Planning

Exhibit # 22-2 Firm Capacity in Megawatts, Line Length up to 50 Miles - Revised Chart #12-20

22-3 Charts referred to by Mr. H. P. Smith (to be supplied)

22-4 Charts used by L. Rubino to illustrate transformer construction to control voltage.(to be supplied)

22-5 Charts referred to by P. Dandeno

22-6 Slide Charts referred to by Ken McClymont

22-7 Slide Charts referred to by A. Waters

Topic #37: Ontario Institute of Agrologists

Exhibit # 37-1 Norman Pearson's Study "Foodland and Energy Planning".

Appendix C

Papers Funded by the Commission

Background Papers

Electric Power Transmission, the Technology and the Problems.	- Omand Solandt (Ivey Paper)
Land Use Implications of Electricity Supply Facilities.	- Norman Pearson

Funded Papers

Food Land Steering Committee

Research includes:

- Impact of large generating stations and transmission lines on food land and the Canadian Shield.
- Ozone-sources and effects.

Christian Farmers Federation of Ontario

Research includes:

- effects of power lines.

University of Waterloo

Research to examine some aspects of hydro-electric transmission corridors related to impacts on the physical and human environments.